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The premotor theory of attention and the Simon effect

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ABSTRACT

In the paper by Hommel (2011-this issue), the roles of the theory of event coding (TEC) and the premotor theory of attention (PMTA) for the Simon effect were considered. PMTA was treated by Hommel in terms of the proposal that attentional orienting can be viewed as the preparation of a saccade towards a certain location, and was dismissed as providing no useful contribution for an attentional explanation of the Simon effect. Here we considered a more recent and broader conception of the PMTA, compared this approach with TEC, and confronted both approaches with a few studies focusing on the role of spatial attention for the Simon effect. It was argued that PMTA may account more easily for various studies examining the influence of spatial attention on the Simon effect. We concluded our paper by listing some elements that an overall encompassing theory on the Simon effect should contain.

1. Introduction

In his tribute to the Simon task, Hommel (2011-this issue) reviews various themes that have derived from the work with this task. In doing so, he certainly accomplishes his goal of underlining the wide application of the Simon task as a tool and heuristic in the exploration of human cognition and action. Moreover, Hommel provides a detailed look into the theoretical kitchen of the Simon effect by sketching its underlying mechanism(s). His paper is centered on the view that Simon effects can be nicely accounted for within the theory of event coding (TEC; Hommel, Müsseler, Aschersleben, & Prinz, 2001). At the same time, a major alternative framework, the premotor theory of attention (PMTA; Rizzolatti, Riggio, Dascola, & Umiltà, 1987), was dismissed on the ground of theoretical problems. We believe that this rejection of PMTA is premature. In the following, we will more closely focus on PMTA and will elucidate the similarities and differences between PMTA and TEC with regard to the Simon effect. Next, we will focus on the implications of the results of a couple of studies examining the influence of spatial attention, and will conclude our comment by specifying the required elements that an overall explanation of the Simon effect should encompass. The latter aims to show that TEC and PMTA explanations are not mutually exclusive, and should probably considered together in explaining the various observations from the Simon literature.

2. The premotor theory of attention (PMTA)

In our view, PMTA implies a central role of spatial attention for the Simon effect. In general, PMTA suggests a facilitation of actions towards attended locations because attentional orienting towards a location is (nearly) equivalent to the general preparation of an action towards that location. Indeed, this comes very close to the original proposal by Simon (1969) that there is "a natural tendency to react towards the source of stimulation". This view can also easily be related to ideas on attention that can be paraphrased as "selection for action" (Allport, 1987; Neumann, 1987; Van der Heijden, 1987). For example, when considering the function of selective attention in vision, Van der Heijden (1992) argued that the major function of attentional selection is not a reduction in the incoming information in itself because of presumed limited processing capacity, but rather to select an appropriate action on the basis of a specific stimulus. To base one's response upon a stimulus implies the selection of the location of this stimulus and to relate (aspects of) this stimulus with a specific action. This view implies that for a stimulus to be used to control behavior, it must be selected by attention, and in our opinion this selection of a location by attention is a prerequisite for any subsequent effect on performance of this location, like in the Simon effect.

In his treatment of PMTA, Hommel (2011-this issue) refers to a rather strict interpretation of this theory based on the original proposal by Rizzolatti et al. (1987). Rizzolatti et al. argued that

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attentional orienting might be conceived of as the preparation of an eye movement towards a certain location. Hommel (2011-this issue) claimed that, when thought through thoroughly, PMTA is "structurally incompatible" to a potential attentional account of the Simon effect, and therefore cannot be seen as a theoretical foundation for the latter. Specifically, he argues that the recoding of space relative to an attended location makes no sense if the eyes are not moved to this location. A more recent conception of PMTA, which appears to be more widely accepted than Hommel suggests, is much broader, and can be summarized as the manifestation of a rather direct link between perception and action that binds perceptually relevant locations to actions in general — and not only to eye movements (e.g., Sheliga, Craighero, Riggio, & Rizzolatti, 1997).

Initially, it was demonstrated that preparation of an eye movement towards a location facilitates the identification of letters at that particular location (Deubel & Schneider, 1996). Later studies showed that letter identification at a particular location is also better when this location is the goal of a pointing movement (Deubel, Schneider, & Paprotta, 1998), in line with the idea that there is a more general link between attentional orienting and action planning. Other evidence indicates that there is also a strong link between the execution of eye movements and manual aiming movements (e.g., see Neggers & Bekkering, 2001).

Neurophysiological support for a close link between attentional orienting, eye movement preparation, and hand movement preparation comes from several electroencephalographic (EEG) studies (e.g., Eimer, Forster, Van Velzen, & Prabhu, 2005; Eimer, Van Velzen, Gherri, & Press, 2006; Van der Lubbe, Neggers, Verleger, & Kenemans, 2006; Van der Lubbe et al., 2000). Specifically, posterior parietal lateralized EEG components sensitive to the relevant spatial location were quite comparable when attending to a location to the left or right from fixation as compared to when a hand or an eye movement had to be prepared to this same location. In addition, in the review paper by Andersen and Buneo (2002); (see also Astafiev et al., 2003) a number of methods were considered (lesion studies, fMRI, and electrophysiological recordings of monkeys), and on the ground of their results it was argued that the posterior parietal cortex (PPC) performs a crucial intermediate role between perception and action by using a distributed spatial representation that is independent of sensory input and motor output (for further support on the ground of an extensive theoretical analysis, see Van der Heijden, 2004). Altogether, this evidence supports the view that spatial attention and the selection of spatially defined actions like eye and hand movements are closely related, which can be explained by an overlap of the involved spatial representations in a shared spatial map.

How then, can the Simon effect be understood in terms of PMTA? Let us focus on a standard Simon task. For example, take a task in which A's or B's are presented to the left or right from fixation accompanied by a mask on the opposite side. A's require a left response and B's require a right responses. This task obviously involves spatial representations related to both the attentional selection of the visual input, selection of the letter, and to the selection of an action in space. According to PMTA, these spatial representations are partially shared. The observation that the letter A presented at the left side of the screen results in a faster left than right response, then, may be seen as due to the shared spatial representations involved in the control of attention and response generation, such that attentional selection of the location containing the relevant stimulus primes the corresponding response.

3. Comparing TEC and PMTA accounts of the Simon effect

In Table 1, we listed several characteristics of both the TEC and PMTA approaches with regard to the Simon effect, and concluded this list with some predictions. As indicated by Hommel (2011-this issue) the relevant processes underlying the Simon effect involve feature codes related to perceived (i.e., stimuli) and produced events (i.e., actions), whereas within the framework of PMTA the relevant processes seem to involve a direct link between spatial maps used for perception and action. Both views assume the involvement of a shared spatial representation (TEC assumes that non-spatial features are shared in addition), but the role of spatial attention is totally different between both accounts.

The central mechanism within the PMTA framework is spatial attention, as selecting a specific location in space immediately primes an action towards that location. Thus, the spatial code can be characterized as a kind of system code and is not necessarily related to the representation of a physical stimulus. In its strictest sense, this view implies that the Simon effect is conditional upon attentional orienting. Thus, a Simon effect should only be observed in the case of attentional orienting, even without the presence of a stimulus. Furthermore, the reference of the involved map is possibly recalibrated after each attentional shift (e.g., Nicoletti & Umiltà, 1989, 1994) to the current locus of attention. On the assumption of a single attentional system, this implies that there can only be one code active at a specific moment in time.

The central aspect of TEC concerns the common coding of spatial stimulus and response features: the same neural codes are used for coding the spatial features of both stimulus and response events. Attention plays a modulatory role in the strength of specific dimensions (i.e., intentional weighting) on the basis of the specific

Table 1
Relevant characteristics of the PMTA and TEC accounts for the Simon effect.

	PMTA	TEC
Relevant level and format of representation	Intermediate between perception and action; spatial	Features codes related to stimuli and perceptual consequences of actions; spatial
Explanation	Identical locations within a shared spatial map	Identical spatial codes for stimuli and responses
Central mechanism	Spatial attention	Common coding of stimuli and responses
Moment of formation of spatial codes	Attention dependent; probably attentional selection of the stimulus	a) Stimulus, or (after onset) b) Attentional selection of a, or (insert afterstimulus) c) Retrieval of a stimulus from memory
Origin of spatial codes	Attention-related	Stimulus/Response related
Number of simultaneous codes	System-dependent (probably only 1)	Stimulus and reference dependent (multiple)
Value of code	Attention dependent; probably the direction of the last shift of attention before response execution.	Reference dependent (attention, or any other possible reference)
Function	Appropriate interaction with the environment	Action monitoring and learning
Critical predictions	No stimulus needed for a Simon effect Attentional shift required Decay relative to the moment of attentional selection	(The representation of) a stimulus is required No attentional shift is required Spatial definition of responses required Decay related to either a) stimulus onset, b) the moment of selecting a stimulus, or c) the moment of retrieving a stimulus from memory

task set, and the locus of attention may serve as one of the multiple references for spatial stimulus codes. An implication is that a Simon effect may very well be observed in the absence of attentional orienting (e.g., when attention is already focused on the target location) as the involved stimuli are coded against multiple references. Conversely, TEC seems to hold the requirement of a physical stimulus (or a representation of a physical stimulus that can be retrieved from memory; Hommel, 2002), as something needs to be referenced. This may be a crucial element in empirically differentiating between PMTA and TEC accounts.

TEC assumes that spatial codes are related to perceived events; unfortunately, as far as we know the precise moment of their formation has never been unambiguously and uniquely specified. For a basic understanding of the Simon effect, however, specifying this moment is of considerable importance as several studies have shown that the Simon effect may decrease for slower responses: the decay effect (e.g., see Hommel, 1994; Van der Lubbe & Verleger, 2002). For example, Hommel (1994) varied stimulus discriminability (high/low), and observed that the Simon effect decreases in the case of low stimulus discriminability. These and many other findings were interpreted as indicating that there is an automatic decay of the involved spatial code.[1] We believe that three alternative moments may be considered. First, given the fact that spatial codes are thought to be strongly related to stimulus events, one might argue that the formation of a spatial code occurs at stimulus onset. A second alternative might be the moment at which a stimulus is made relevant, for example, by a specific instruction. In the latter case, this moment is apparently the moment at which a stimulus is selected by attention. Third, one could argue that spatial codes are formed at the moment at which a particular event is retrieved from memory (such as in the study of Hommel, 2002). The latter option, however, is not relevant for most Simon studies, and also would be hard to distinguish theoretically from the first alternative (i.e., an internally generated stimulus is still a stimulus). Only based on specified moments of spatial code generation can decay – as well as the overall TEC account for spatial code generation – be well understood[2]; also, only once this moment is clearly specified can decay be possibly used as a diagnostic tool in distinguishing between different (though not necessarily mutually exclusive) accounts of the Simon effect.

The PMTA perspective implies that the crucial moment from which decay sets off is the moment of attentionally selecting a stimulus, and not the moment of presenting a stimulus (although these moments often coincide). Thus, according to PMTA decay should be related to the moment of attentional selection, whereas this moment may be mostly related to either stimulus onset or the moment of attentional selection of a stimulus according to TEC.

4. Recent studies examining the role of spatial attention for the Simon effect

In his paper, Hommel (2011-this issue) indicates that spatial attention is not crucial for spatial code generation in the Simon task, which seems to be underlined by the remark that "almost none of the available studies provided any evidence that the assumed attentional shifts are actually taking place… which basically renders attention-shifting theorizing circular". Although we acknowledge that sometimes there may be a tendency to circular reasoning because of doubts

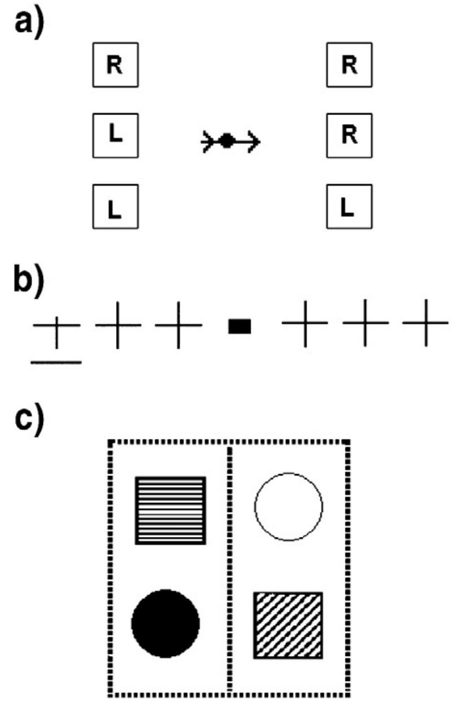

Fig. 1. In panel a, an example of the stimuli employed by Van der Lubbe et al. (2005) is presented. The central arrow was presented either 500 ms before (precue), simultaneously with, or 500 ms after filling the boxes (postcue) with the letters L or R, which required a left or right button press, respectively. In panel b, an example is given of the multiple item arrays used by Van der Lubbe and Woestenburg (1999), in which a target, requiring either a left or right response, was preceded either by a cue indicating the precise target position (indicated here), or a cue indicating the relevant side at which the target would occur, or a cue indicating all array positions. In panel c, an example is given of the stimuli employed by Hommel (2002), in which the frame was colored, and indicated which of the elements had to be selected to determine the required response. In two experiments, the elements were not even present at the moment when the frame was colored, implying that responses had to be made based on the memorized objects.

whether an attentional manipulation really worked, it appears possible to provide support for an attentional shifting, for example by using attention-dependent measures derived from the EEG (e.g., Eimer, 1996; Van der Lubbe, Jaśkowski, & Verleger, 2005; Wascher & Wolber, 2004; Wiegand & Wascher, 2005). In the following subsections we will discuss studies that clearly indicate the involvement of spatial attention in the Simon effect, and which can be accounted for by PMTA – at least – equally well as by TEC.

4.1. Studies using precues: the link between attentional orienting and the Simon effect

In the study by Van der Lubbe et al. (2005), participants had to keep their eyes directed at a central fixation point. Two columns of three boxes were presented, one column to the left and the other column to the right side from fixation (Fig. 1a). Next, a precue (an arrow) pointed to one of the boxes, and 500 ms after arrow onset all boxes were pseudo-randomly filled with the letters L or R.[3] Participants were instructed to press a left or right button with their corresponding hand to the corresponding letter L or R. In a simultaneous cue condition, the arrow was presented at the same moment as the letters, and in another postcue condition (discussed in the postcue section), the cue appeared 500 ms after presenting the

[1] At least this applies to standard versions of a visual Simon task with horizontal stimulus and response arrangements. Some studies with vertical stimulus and response arrangements, however, reported no decay (e.g., see Wiegand & Wascher, 2007; but see De Jong et al., 1994).

[2] Without specification of the moment of spatial code generation we end up with a version of TEC that allows multiple references to be at the basis of multiple spatial codes that are formed across multiple (unspecified) moments in time, hence creating a nearly unfalsifiable theory.

[3] According to the logic of Kornblum, Hasbroucq, and Osman (1990) using L's and R's as imperative stimuli suggests that this task may be characterized as a spatial Stroop task as there is dimensional overlap between stimuli and responses. However, this overlap was not manipulated and therefore cannot be held responsible for any of the observed effects.

letters. In the precue condition, a Simon effect of 12 ms was observed, and this effect was of comparable magnitude in the simultaneous cue condition (9 ms). Thus, despite the possibility to attend to the relevant box before presenting the target, no reduction of the Simon effect was found, which at first sight disagrees with the predictions of the PMTA. The authors reasoned that the manipulation of attention may not have been optimal, which may sound like circular reasoning. Inspection of the EEG, however, suggested that attention was indeed reoriented at a later moment in time, as a posterior contralateral negativity (PCN/N2pc) was observed approximately 200 ms after array onset. Thus, in fact, this observation confirms the idea that there is a relation between attentional orienting and the Simon effect in line with the predictions of the PMTA.

Let us focus on a possible explanation in terms of TEC for the precue condition. In this condition, three L's and three R's were presented, and all these stimuli may have been referenced against multiple reference frames.[4] This seems to imply the presence of numerous and several conflicting spatial codes according to TEC. The fact that nevertheless a clear Simon effect was present obviously requires the involvement of attention. Thus, there may have been increased activation of the spatial feature of the target stimulus (due to attentional selection), and also, for some reason, this extra activation mainly concerned a spatial eye-centered map. This implies that – even within the framework of TEC – spatial attention appears to be a necessary element for the explanation. Other studies (see later discussion) revealed more effective manipulations of spatial attention, both by using exogenous and endogenous precues.

Van der Lubbe and Woestenburg (1999) also employed multiple item arrays, but they presented three elements to the left and three elements to the right from fixation in a single row (Fig. 1b). One of the elements was the target, which was presented either next to fixation (the inner positions), or at one of the outer array locations. The target required a left or right button press with the corresponding hand, and the other five elements were distractors. The arrays were preceded by one out of three different types of cues that varied in the number of precued positions. One cue, a small line, was presented just below the subsequent target location. A second cue, a longer line, indicated one side of the array, the side in which the target was embedded, and a third cue, an even longer line, cued all the subsequent array elements. The type of cue was held constant during a block of trials. No Simon effect was found when the cue indicated the precise target location (3 ms), whereas a clear Simon effect was obtained (14 ms) when all array elements were precued. Interestingly, when one side of the array was precued, a Simon effect was present for the outer array locations (17 ms), whereas a weak tendency to an opposite effect was found for the inner array locations (−5 ms). In line with PMTA, these findings may indicate that no attentional orienting was necessary when the target was precisely cued, but clearly so when all array elements were cued. In the case of the side cue, the likely final direction of attentional orienting was either corresponding (for the outer positions) or noncorresponding (for the inner positions) with the response side, which may explain the discrepancy between the inner and outer array positions in this condition.

Alternatively, along the lines of TEC, it may be argued that on each trial the spatial code of the to-be-selected target was re-referenced to the new locus of attention, thereby implying 1) a neutral (attention-centered) spatial code of the target when the target location was uniquely precued, 2) an eye-centered spatial target code when all array elements were precued, and 3) a different attention-dependent spatial target code depending on the inner or outer array location when the arrays were preceded by side cues. This indicates that, in order to explain these results within the TEC framework, attention must fulfill multiple roles at nearly the same time, as it serves both as a new reference but also as mechanism to select the target and thereby selectively activate its corresponding spatial code. The question then arises to what extent – if any – such a version of TEC is still distinguishable from a PMTA account.

In a number of other studies, the influence of spatial attention was examined by using valid and invalid exogenous and endogenous cues (for a review, see Abrahamse & Van der Lubbe, 2008). Abrahamse and Van der Lubbe (2008) reported two new experiments in which a strong reduction of the Simon effect was observed when targets appeared at endogenously cued as compared to uncued locations. The employed endogenous cues consisted of two differently colored triangles pointing to a left and a right circle. The relevant color varied per condition, and indicated with a validity of 80% in which circle the target (requiring a left or right button press with the corresponding hand) would appear. The cued side varied from trial to trial. The target was presented at 1000 ms after cue onset. The Simon effect on invalidly cued trials amounted to 54 ms, and was reduced to 21 ms on validly cued trials. These results were replicated in a second experiment. The orienting of attention towards the cued location in the cue-target interval was confirmed by EEG analyses presented in an earlier paper (Van der Lubbe et al., 2006). In line with TEC, these findings may indicate that the locus of the reference differs between validly cued and invalidly cued trials, or in line with PMTA, it may be argued that the reorienting of attention was especially needed on invalidly as compared to validly cued trials, thereby producing an enhanced Simon effect on these trials. Although these studies with precues do not invalidate the TEC account for the Simon effect, they especially fit the PMTA account (see Table 1) as it appears that spatial attention plays an important role for the Simon effect.

4.2. Studies using postcues: the decay of spatial codes

In the abovementioned study by Van der Lubbe et al. (2005) multi-item arrays were presented, consisting of two columns of three elements (Fig. 1a). In one postcue condition, the arrays were followed by a cue that indicated the target 500 ms after array onset. Despite the fact that the arrays were presented much earlier, allowing sufficient time for decay relative to stimulus onset, the Simon effect was not reduced in this postcue condition (18 ms) as compared to the condition with the simultaneously presented cue (9 ms). Furthermore, a posterior lateralization was present in the EEG at about 250 ms after presenting the cue, in line with the idea that attention was shifted towards the relevant location. These findings indicate that the decay of the Simon effect probably depends on the moment of selecting a stimulus by attention and not stimulus onset. This observation seems perfectly in line with PMTA, and can be accounted for by the version of TEC (see Table 1) on the assumption that the spatial code is formed when selecting a stimulus and not at the moment of its onset.

In another study, reported by Hommel (2002), results were obtained that seem perfectly in accordance with the previous observations. In this study, arrays consisting of four elements (circles or squares) were employed, with each element appearing in a white frame that was divided into two columns, each containing two elements (left up, left down, etc., see Fig. 1c). Each element was displayed in another color. The color of the frame subsequently changed and cued which of the objects (the one with the same color) had to be selected to determine the appropriate left or right key. Interestingly, a clear Simon effect (approximately 50 ms) was observed, being largest with the maximum time interval of 1500 ms between the array and the subsequent cue. Thus, no decay of the Simon effect was observed at all, supporting the idea that formation of the spatial code is not related to the real onset of a stimulus. In two additional and even more convincing experiments, the objects were no longer present upon the arrival of the cues. Responses had to be made based on the memorized objects, and even in these conditions

[4] The arrow was presented much earlier in this condition, and therefore, its features seem unlikely to have played a role for the Simon effect.

clear Simon effects (approximately 20 ms) were observed depending on the previous location of the relevant object. At first sight, these findings seem difficult to account for within the framework of TEC as the relevant stimuli (and related spatial features) are no longer present (see Table 1), but the results can be explained by attentional shifts towards the memorized locations. A rather different explanation was forwarded by Hommel (2002). He argued that object files are created upon the presentation of the four elements, in line with the ideas of Kahneman, Treisman, and Gibbs (1992). Furthermore, he reasoned that this object file can be mentally recreated upon the arrival of the postcue implying reactivation of the spatial feature thereby providing an explanation for the Simon effect. Apparently, the moment of formation of the relevant spatial code appears not at all related to any physical feature, which seems far off from the original idea of TEC (see, Hommel, 2011-this issue) that spatial codes are related to perceived events.

5. Required elements for an overall encompassing explanation of the Simon effect

On the basis of the foregoing, we believe that the following elements are essential for a full account of the Simon effect. A first requirement, which is implied both within the TEC and PMTA framework, is the need for a common representational level for the internal coding of (relevant) stimuli and (relevant) responses to allow for any crosstalk.

Secondly, the role of attention needs to be specified more precisely as attentional selection, and the moment of this selection, appears to be a prerequisite for the Simon effect, at least in all the aforementioned studies. The role of attention for the Simon effect is clear from the perspective of PMTA: attentional selection of a location implies that actions towards this same location are temporally facilitated due to a shared spatial representation of stimulus and response locations. Hence, spatial code generation is time-locked to attentionally selecting the stimulus. As noted previously, three alternative moments of spatial code generation can be considered for TEC, but only one of these seems to fulfill the necessary requirements: the variant implying that spatial codes are formed at the moment of attentional selection of a stimulus. This seems to hold the following specifications: the locus of attention is at least one of the most important reference frames, and attentional selection determines which spatial code related to a specific stimulus will exert an effect, and the moment of its formation also coincides with the moment of attentional selection. One might argue that the dual role of attention implicated by this version of TEC is less parsimonious than the role of attention as considered by PMTA. Furthermore, it appears that this further specification of TEC makes PMTA and TEC nearly indistinguishable.

A third requirement appears to be a need for incorporating higher level cognitive codes as well, because Simon effects are dependent on meaningful contexts such as the presence of a rotated face (Hommel & Lippa, 1995). In confirmation of the previous aspect, there is support for the involvement of multiple stimulus spatial codes that cannot all be traced back to attentional orienting (Lamberts, Tavernier, & d'Ydewalle, 1992; see also Lleras, Moore, & Mordkoff, 2004). Obviously, this requirement is beyond the scope of PMTA, whereas TEC has enough degrees of freedom to enable an account. Nevertheless, the reason why in specific experiments higher level codes prevail above lower level codes remains to be specified. Fourth, if there is indeed contribution of two different representational levels, a low spatial level and a higher cognitive level, then there is also need for a common representational format for stimulus and response information, for both types of interference (low-level and high-level). For example, a selected stimulus and a specific response may concern the same location in a shared spatial map, and they may both contain the same associated semantic label “left” or “right”.

A recent proposal that may come close to these requirements was presented by Wiegand and Wascher (2005, 2007), (see also Buhlmann, Umiltà, & Wascher, 2007; Matsumoto, Misaki, & Miyauchi, 2004), which may be viewed as an update of the dual route model proposed by De Jong, Liang, and Lauber (1994). Wiegand and Wascher make a distinction between two relevant mechanisms. One mechanism concerns a direct visuomotor pathway (possibly the dorsal visual pathway), and may be related to the PMTA proposal previously discussed. Another, more cognitive mechanism is thought to be involved in the case when more complex S–R translations have to be carried out (possibly involving the ventral pathway). This distinction between a visuomotor and a cognitive code may help to clarify results, and may offer an integration of both the TEC and PMTA perspectives.

6. Conclusion

Hommel's (2011-this issue) rather selective tour through the Simon landscape may be well justified for the purpose of inspiration. However, we feel that some routes in this landscape are presented as dead-ends, while actually they provide a clear and complementary explanation for a large range of findings that cannot be easily explained within the framework of TEC. Specifically, we believe that TEC does a great job in dealing with cognitive or memory-based Simon effects, but is limited in explaining a range of other findings that strongly suggest the involvement of spatial attention in the Simon task. Obviously, we do not believe that attentional shifting is responsible for all the effects on performance of laterally presented stimuli. However, we just feel that there is – on the base of current understanding – no reason to reject the idea that an attention shift code is at work in parallel to various stimulus-related codes. New and clearly specified theories on the Simon effect should take into account that both lower level attentional codes and higher level cognitive codes are necessary ingredients for an overall encompassing theory on the Simon effect.

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